LAWRENCE

The Effects of Waterproofing Ingredients upon the Strength of Concrete

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THE EFFECTS OF WATERPROOFING INGREDIENTS UPON THE STRENGTH OF CONCRETE

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I recommend that the thesis prepared under my supervision by CHARLES WESLEY LAWRENCE entitled The Effect of Waterproofing Ingredients upon the Strength of Concrete be approved as fulfilling this part of the requirements for the degree of Bachelor of Science in Civil Engineering.

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I. INTRODUCTION.

Concrete, as ordinarily made and placed in structural work, is permeable to water, hence to secure immunity of concrete structures from the damaging influences of water in its discomforting, unhealthy, or destructive features, some method of waterproofing the concrete must be used. It is desirable that all masonry structures be waterproof, and it is indispensable in certain structures such as basements, tunnels, reservoirs, and roofs.

Although the practice of waterproofing is comparatively new, there are several methods in use and they may be divided into groups as follows: (1) the use of the impervious shield or diaphram consisting usually of a bituminous layer; (2) the use of waterproof coatings or washes; (3) the so-called integral method, in which foreign compounds are incorporated in the concrete and render it impervious to water by their void-filling or water-repelling qualities; (4) the use of a dense concrete which is secured by the careful selection of the materials so that the voids are largely eliminated. The liberal use of cement, careful grading of sizes of rock materials, and dry mixing all tend to imperviousness.

When a foreign compound is added the ingredients usually employed are as follows: (1) liquid compounds

which are added to the water in mixing the cement and which are usually some form of chloride of lime, sulphate of aluminium or oil emulsion; (2) powdered dry materials which are added to the cement before mixing, and which are usually hydrated lime and metallic stereates, which are usually chlorides; (3) soap and alum, which are employed in the Sylvester process, in which a powdered aluminium compound is added to the cement, and ordinary soap is added to the water.

Although several of these compounds have been used extensively in concrete, the effect that they produce is largely a matter of conjecture. In most cases their ability to render the concrete impervious has been proved, but the effects they produce upon the strength and durability have not been definitely ascertained. Experiments to determine the effects of waterproofing on the properties of concrete other than permeability seem to have been undertaken in a few cases, but the investigations so far as the writer has been able to find have not been extensive and the results derived were consequently of no great value.

Mr. M. H. Lewis read a paper before the Municipal Engineers of the City of New York on November 25, 1908, in which he discussed the different methods of waterproofing. He gave the results of some experiments made to determine the effect of waterproofing materials upon neat cement and mortar. The following conclusions were drawn

from the use of 2 per cent Hydratite (a compound made by the A. C. Horn Co.) in neat portland cement and also in 1:2 cement mortar: (1) the rate of setting is somewhat retarded by the use of this compound; (2) the compound decreases the strength of neat cement; (3) the compound increases the strength of cement mortar; (4) the adhesive power of old to new work is increased by the use of the compound.

The use of Aquarex, made by the Knickerbocker Chemical Co.; Maumee, made by the Maumee Chemical Co.; Medusa, made by the Sandusky Portland Cement Co.; and Hydratite, all in 1:5 mortars gave the following results: After six months the waterproofed mortar tested weaker in tension and compression in every case than the pure cement mortar; for shorter periods of time the treated mortar was in some cases stronger than the pure cement mortar. Mr. Lewis gave no data on tests of concrete and it is probable that few if any such tests have ever been made, as the writer has not been able to find any records of such tests.

When the engineer wishes to select a waterproofing compound the question arises as to how the compounds whose effectual waterproofing qualities have been established will affect the strength and durability of the structure.

Authentic information however can not be readily obtained, on account of the fact that the effects of

waterproofing compounds upon concrete have not been carefully investigated. For this reason the experiments described in the following pages were undertaken in the hope of increasoing to some extent the present knowledge on the subject.

II. DESCRIPTION OF TESTS.

SCOPE.

In selecting the waterproofing materials for the tests an endeavor was made to choose some of those which have been successfully used in rendering concrete impervious and are in common use. The ones selected are as follows: soap and alum; Medusa; Maumee; Trus-Con; Anti-Hydro; and Hercules, all but the first being proprietary compounds. Each in turn was incorporated in neat cement, in mortar, and in concrete, and the treated mixtures were then subjected to the following tests: (1) the cold pat test for constancy of volume; (2) test for tensile strength of neat cement; (3) test for tensile strength of 1:3 mortar; (4) test for compressive strength of 1:3:5 concrete in 6-in. cubes. Tests were also made of specimens of the ordinary materials without the admixture of any waterproofing compound. The tests of the untreated specimens were conducted, so far as possible, in exactly the same manner as the tests of those which contained the waterproffing compounds, in order to determine the effects produced by the ingredients used. A full description of the materials and methods is given in the detailed account of the experiments in the following pages.

MATERIALS.

Cement.--The cement used in the tests was "Chicago A A" portland, manufactured by the Chicago Portland Cement Co. of Chicago, Illinois, and it was selected from that sold in the open market. This cement has an extensive sale in the middle west.

Sand.--The sand was a variety known as Wabash sand and came from Attica, Indiana. It consists of a mixture of gravel and sand with 1.5% of clay. Before use it was dried thoroughly by heating in pans. Only that part of the sand passing a 7/32-in. sieve was used.

Stone.--The stone was selected from a quantity of Kankakee limestone which had been crushed and graded to pass through a 1-in. ring. It had been stored in a dry place for about one year. The stone was separated into two parts, that between 3/4-in. and 3/8-in. in size and that between 3/8-in. and 7/32-in. in size.

Waterproofing Compounds.--Maumee waterproofing compound is a proprietary article manufactured by the Maumee Chemical Co., of Toledo, Ohio. It is a fine white powder and is put up in 50-pound paper lined cloth sacks. The directions for its use as given by the manufacturer, are to mix 2 per cent of Maumee with the cement while dry. The mixture is then added to the other materials of the concrete in the usual way.

Medusa is a proprietary compound made by the Sandusky Portland Cement Co., of Sandusky, Ohio. It is

a white powder and is put up in 40-pound sacks. A quantity of the compound equal to 2 per cent of the weight of the cement is added to the cement when mixing the concrete.

Trus-Con waterproofing paste is manufactured by the Trussed Concrete Steel Co., of Detroit, Michigan. It is a thick yellow-colored paste and is put up in tin packages of 40, 80, and 360 pounds capacity. Trus-Con is used by mixing one part with 12 parts of water by weight and tempering the dry mixture of cement and aggregate with this solution.

Anti-Hydro is made by the American Diamond Blast Co., of New York. This compound is a liquid somewhat thicker than water and it is almost colorless. It is used in concrete by adding to the water 10 per cent of its own weight of Anti-Hydro. It comes in tin vessels holding 5 gallons or more.

Hercules is manufactured by the Hercules Waterproof Cement Co., of Lasalle, New York. It is a fine white powder, and it is mixed with the dry cement in the proportion of 2 per cent Hercules to 98 per cent cement. It is also manufactured to some extent in paste and liquid forms, but in the following tests only the powdered form was used.

In the soap and alum or Sylvester's process, aluminium sulphate ($Al_2(SO_4)_3$) and Ivory soap were used. The aluminium sulphate was reduced to a powder before use and dissolved with the soap in the water used to mix the concrete.

METHODS.

The tests were made in the cement laboratory of the University of Illinois, which is equipped with the usual apparatus found in a complete cement testing laboratory.

The apparatus and equipment used in these tests included slate-covered tables, Fairbanks small balances and platform scales, brass gang briquette molds, recommended by the American Society of Engineers, Fairbanks testing machine, Riehle 200,000 pound testing machine, steel gang molds for 6-in. concrete cubes, and a specially constructed, hand operated, stone and gravel grading machine.

Test For Constancy Of Volume.--In the test for constancy of volume, two pats were made of untreated neat cement and two of neat cement paste containing the waterproofing material. One pat of each kind was stored in water and the other in air in the laboratory. They were examined at intervals of about one week for 28 days for evidence of unsoundness.

Time Of Set.--Tests for the determination of the time of initial and final set were made with the Vicat needle on untreated cement paste of normal consistency and on pastes treated with the waterproofing compound.

Tension Tests Of Neat Cement.--Briquettes were made of untreated neat cement, and by the addition of each

of the waterproofing compounds to neat cement. Fifteen briquettes of each kind were made in sets of 5. One set of the briquettes was tested at the age of one week, one set at the age of 28 days, and one at the age of three months.

Tension Tests Of 1:3 Cement Mortar.--Briquettes were made of untreated mortar consisting of 1 part cement and 3 parts sand and also of the same mortar treated with the waterproofing material to be tested. Fifteen briquettes were made of each kind by making 5 at one time, and the briquettes were tested at the three ages of 7, 28, and 90 days as in the tension test of neat cement.

Compression Tests Of 1:3:5 Concrete In 6-Inch Cubes.--Six cubes of untreated concrete were made and 6 of the same concrete treated with the waterproofing compound. A quantity of concrete sufficient to make the 6 cubes was made in one mix. For the coarse aggregate of the concrete, 45% of the larger of the two sizes of limestone (see page 6) was used. In making all the concrete 7.7% of water was used. The cubes were taken from the molds at the age of 48 hours and stored in moist sand. Three of the cubes of each set were tested at the age of 28 days and the other three at the age of 4½ months.

III. RESULTS.

The pats made and tested in the constancy of volume test all remained sound, the waterproofing compounds producing no evidence of unsoundness in any case.

The data obtained from the test for the time of set of neat cement are given below. The waterproofing ingredients hastened the time of set in almost every case. The time required for initial set of paste treated with Trus-Con was about the same as for the untreated paste. The use of Hercules waterproofing compound hastened the time of set about 1 hour. The shortest time required for final set was 3 hours 36 minutes, required for the paste to

TIME OF SET OF NEAT CEMENT.

Waterproofing Compound Used.	Time of Initial Set.	Time of Final Set.
None	2 hrs. 40 min.	4 hrs. 31 min.
Maumee	2 " 15 "	3 " 48 "
Medusa	2 " 20 "	4 " 54 "
Hercules	1 " 40 "	4 " 15 "
Anti-Hydro	1 " 46 "	3 " 36 "
Trus-Con	2 " 45 "	4 " 5 "
Soap and Alum	2 " 14 "	4 " 18 "

which Anti-Hydro was added. This was about 1 hour less than the time required for final set of untreated neat cement.

The ultimate tensile strength of the neat cement briquettes is given in Tables 1, 2, and 3. All of the treated briquettes had a lower tensile strength than the untreated at the same ages. The relative strength of the treated and untreated briquettes for different ages is given in Table 9.

The ultimate tensile strength of the 1:3 cement mortar briquettes is given in Tables 4, 5, and 6. The treated briquettes seemed to be weaker than the untreated at the age of 7 days, but at 3 months most of them were stronger than the untreated briquettes. Table 10 gives the relative strength of the treated and untreated mortar briquettes.

The compressive strength of 1:3:5 concrete is given in Tables 7 and 8. The waterproofing compounds seemed to weaken the concrete in every case. The relative strength of the treated and untreated concrete cubes is given in Table 11.

TABLE 1.

TENSILE STRENGTH OF NEAT CEMENT TREATED WITH VARIOUS WATERPROOFING COMPOUNDS.

Age of Briquettes 7 days.

Waterproofing Compound Used.	Tensile Strength of Neat Cement lb. per sq. in.	
	Individual Briquettes	Average
None	800 750 750 780 800	776
Medusa	700 770 710 730 720	726
Maumee	690 710 770 760 690	724
Hercules	710 720 710 700 710	710
Anti-Hydro	720 790 740 800 810	772
Trus-Con	740 720 710 700 710	716
Soap and Alum	770 630 750 750 750	730

TABLE 2.

TENSILE STRENGTH OF NEAT CEMENT TREATED WITH VARIOUS WATERPROOFING COMPOUNDS.

Age of Briquettes 28 days.

Waterproofing Compound Used.	Tensile Strength of Neat Cement lb. per sq. in.	
	Individual Briquettes	Average
None	820 825 795 750 820	804
Medusa	725 690 700 710 720	709
Maumee	740 690 740 760 710	728
Hercules	765 800 770 800 700	767
Trus-Con	750 760 700 690 780	736
Anti-Hydro	700 690 750 740 780	732
Soap and Alum	610 590 630 680 590	640

TABLE 3.

TENSILE STRENGTH OF NEAT CEMENT TREATED WITH VARIOUS WATERPROOFING COMPOUNDS.

Age of Briquettes 3 months.

Waterproofing Compound Used	Tensile Strength of Neat Cement lb. per sq. in.	
	Individual Briquettes	Average
None	855 850 830 750 740	805
Medusa	650 705 640 690 720	681
Maumee	620 660 750 750 730	702
Hercules	760 810 790 790 790	788
Trus-Con	700 700 750 750 675	715
Anti-Hydro	720 750 695 740 685	718
Soap and Alum	725 710 600 635 660	666

TABLE 4.

TENSILE STRENGTH OF 1:3 CEMENT MORTAR TREATED WITH VARIOUS WATERPROOFING COMPOUNDS.
Age of Briquettes 7 days.

Wateproofing Compound Used.	Tensile Strength of Mortar lb. per sq. in.	
	Individual Briquettes	Average
None	350 320 365 315 340	338
Medusa	320 330 330 335 350	333
Maumee	340 335 330 335 300	328
Hercules	350 335 345 325 320	335
Anti-Hydro	310 315 305 325 300	311
Trus-Con	370 370 400 350 400	378
Soap and Alum	300 305 300 315 300	304

TABLE 5.

TENSILE STRENGTH OF 1:3 CEMENT MORTAR TREATED WITH VARIOUS WATERPROOFING COMPOUNDS.

Age of Briquettes 28 days.

Waterproofing Compound Used.	Tensile Strength of Mortar lb. per sq. in.	
	Individual Briquettes	Average
None	420 430 395 410 460	423
Medusa	390 400 375 405 395	393
Maumee	375 350 400 355 355	367
Hercules	415 425 450 420 350	427
Trus-Con	400 430 390 380 400	400
Anti-Hydro	300 305 300 300	302
Soap and Alum	350 315 300 330 320	323

TABLE 6.

TENSILE STRENGTH OF 1:3 CEMENT MORTAR TREATED WITH VARIOUS WATERPROOFING COMPOUNDS.

Age of Briquettes 3 months.

Waterproofing Compound Used.	Tensile Strength of Mortar lb. per sq. in.	
	Individual Briquettes	Average
None	440 415 420 450 420	429
Medusa	470 430 460 500 450	462
Maumee	450 450 450 410 480	444
Hercules	435 490 460 450 460	459
Trus-Con	440 470 490 480 490	474
Anti-Hydro	440 400 410 430 370	410
Soap and Alum	400 380 360 425 410	396

TABLE 7.

COMPRESSIVE STRENGTH OF 1:3:5 CONCRETE TREATED WITH VARIOUS WATERPROOFING COMPOUNDS.
Age of Cubes 1 month.

Waterproofing Compound Used.	Compressive Strength of Concrete lb. per sq. in.	
	Individual Briquettes	Average.
None	1,860 2,040 1,838	1,910
Maumee	2,080 1,810 1,880	1,920
Medusa	1,790 1,620 1,810	1,780
Trus-Con	1,800 1,980 1,920	1,900
Anti-Hydro	1,600 1,830 1,680	1,700
, Hercules	1,550 1,450 1,630	1,540
Soap and Alum	1,540 1,490 1,580	1,530

TABLE 8.

COMPRESSIVE STRENGTH OF 1:3:5 CONCRETE TREATED WITH VARIOUS WATERPROOFING COMPOUNDS.

Age of Cubes 4½ months.

Waterproofing Compound Used.	Compressive Strength of Concrete lb. per sq. in.	
	Individual Briquettes	Average
None	3,360 3,340 3,350	3,350
Maumee	2,920 2,980 2,750	2,880
Medusa	2,960 2,520 2,820	2,840
Trus-Con	3,280 2,970 3,320	3,190
Anti-Hydro	3,110 3,110 3,130	3,120
Hercules	2,760 2,800 2,700	2,770
Soap and Alum	2,290 2,330 2,420	2,340

TABLE 9.

RELATIVE STRENGTH OF TREATED AND UNTREATED NEAT CEMENT BRIQUETTES.

Chicago AA Portland Cement.

aterproofing Compound Used.	Relative Strength		
	7 days	28 days	3 months
one	100	100	100
Medusa 2% of the weight of the cement	93	88	85
Maumee 2% of the weight of the cement	93	90	87
Hercules 2% of the weight of the cement	91	95	98
Trus-Con 7.7% of the weight of the cement	92	92	89
Anti-Hydro 10% of the weight of the water	99	91	89
Soap and Alum $Al_2(SO_4)_3$, 1% of the weight of the water Soap, 3% of the weight of the water	94	80	83

TABLE 10.

RELATIVE STRENGTH OF TREATED AND UNTREATED CEMENT MORTAR.
Chicago AA Portland Cement.

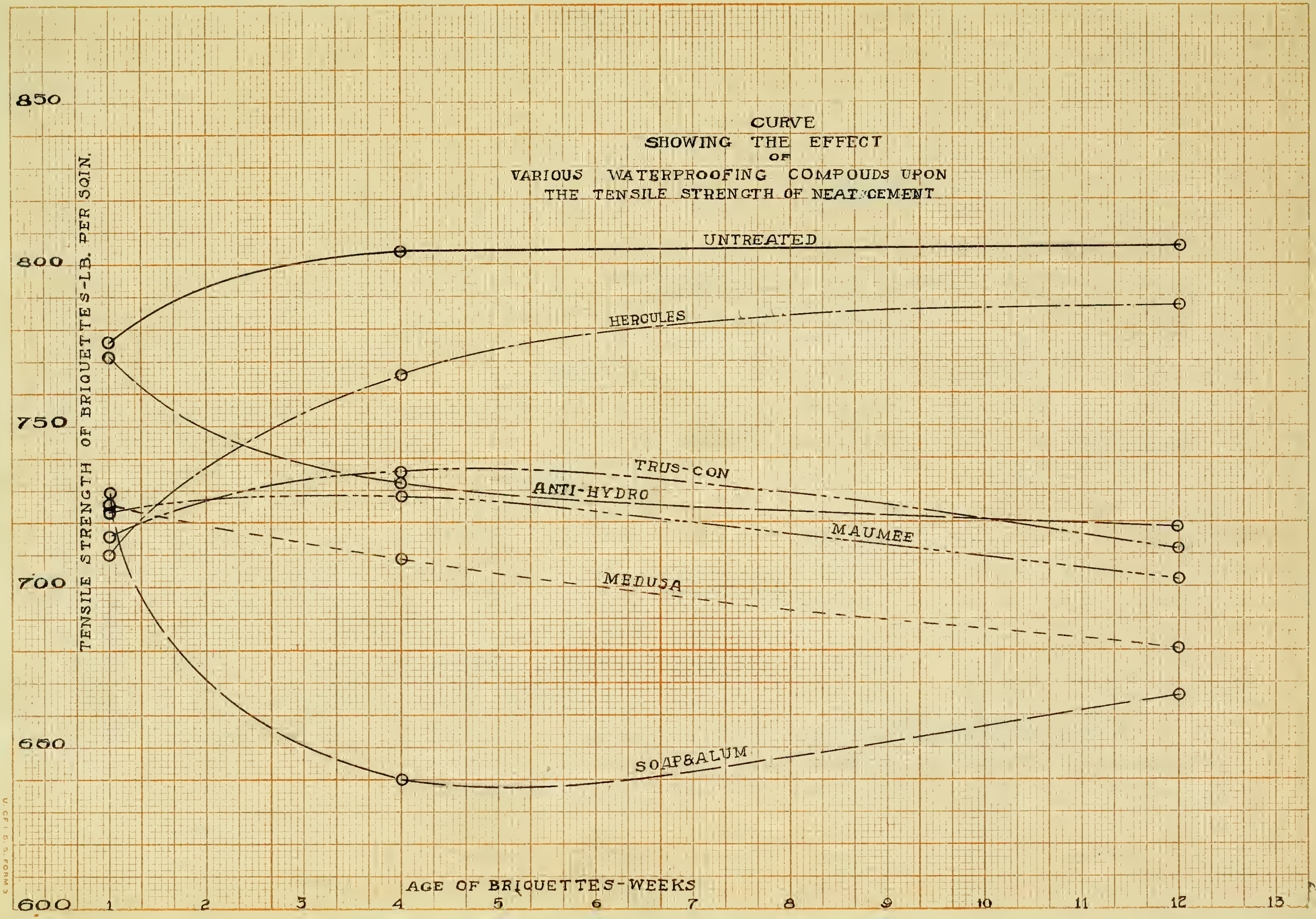
Waterproofing Compound Used.	Relative Strength		
	7 days	28 days	3 months
None	100	100	100
Medusa 2% of the weight of the cement	98	93	108
Maumee 2% of the weight of the cement	97	87	103
Hercules 2% of the weight of the cement	99	101	107
Trus-Con 7.7% of the weight of the water	112	94	110
Anti-Hydro 10% of the weight of the water	92	72	95
Soap and Alum $Al_2(SO_4)_3$, 1% of the weight of the water Soap 3% of the weight of the water	90	76	92

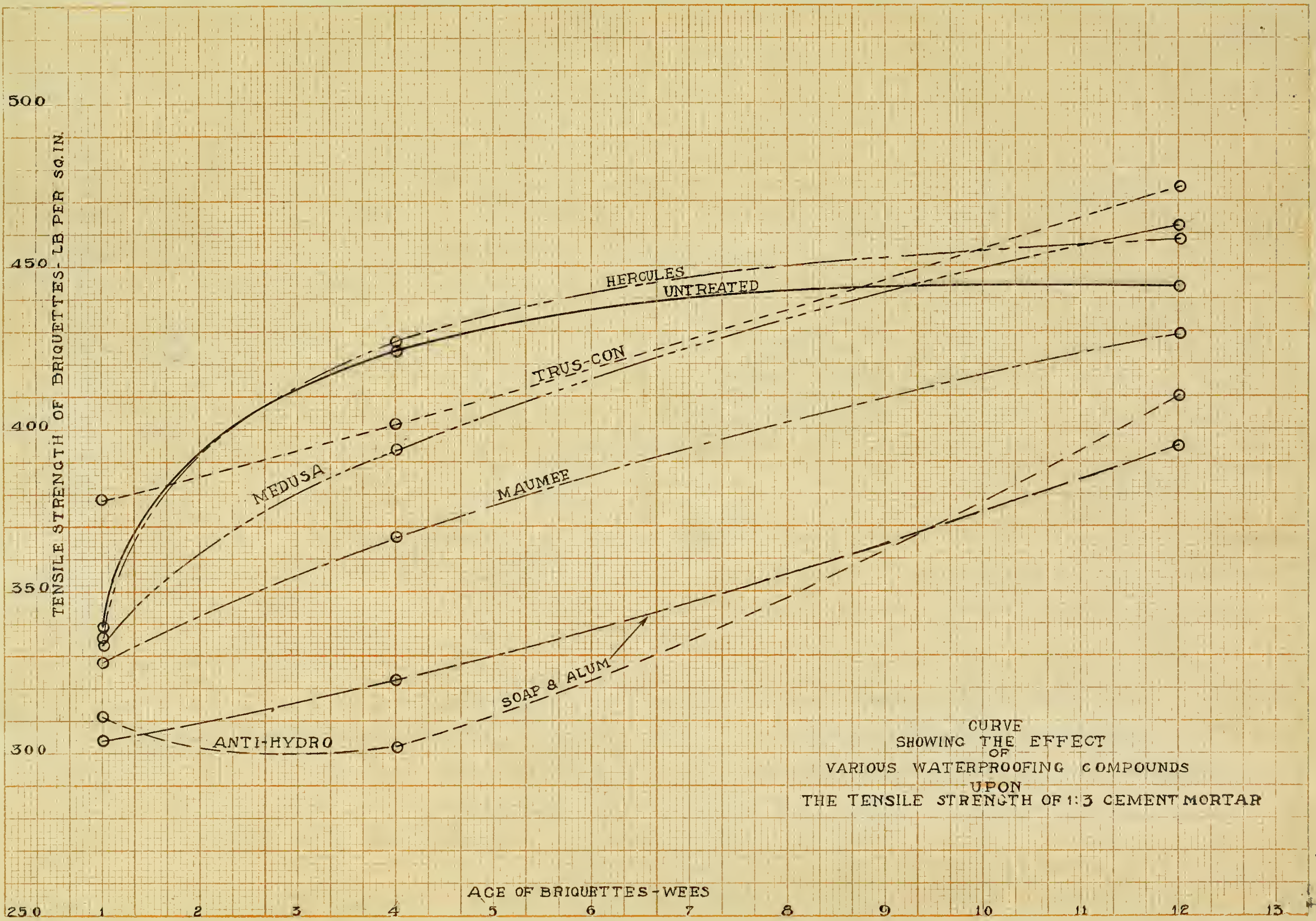
TABLE 11.

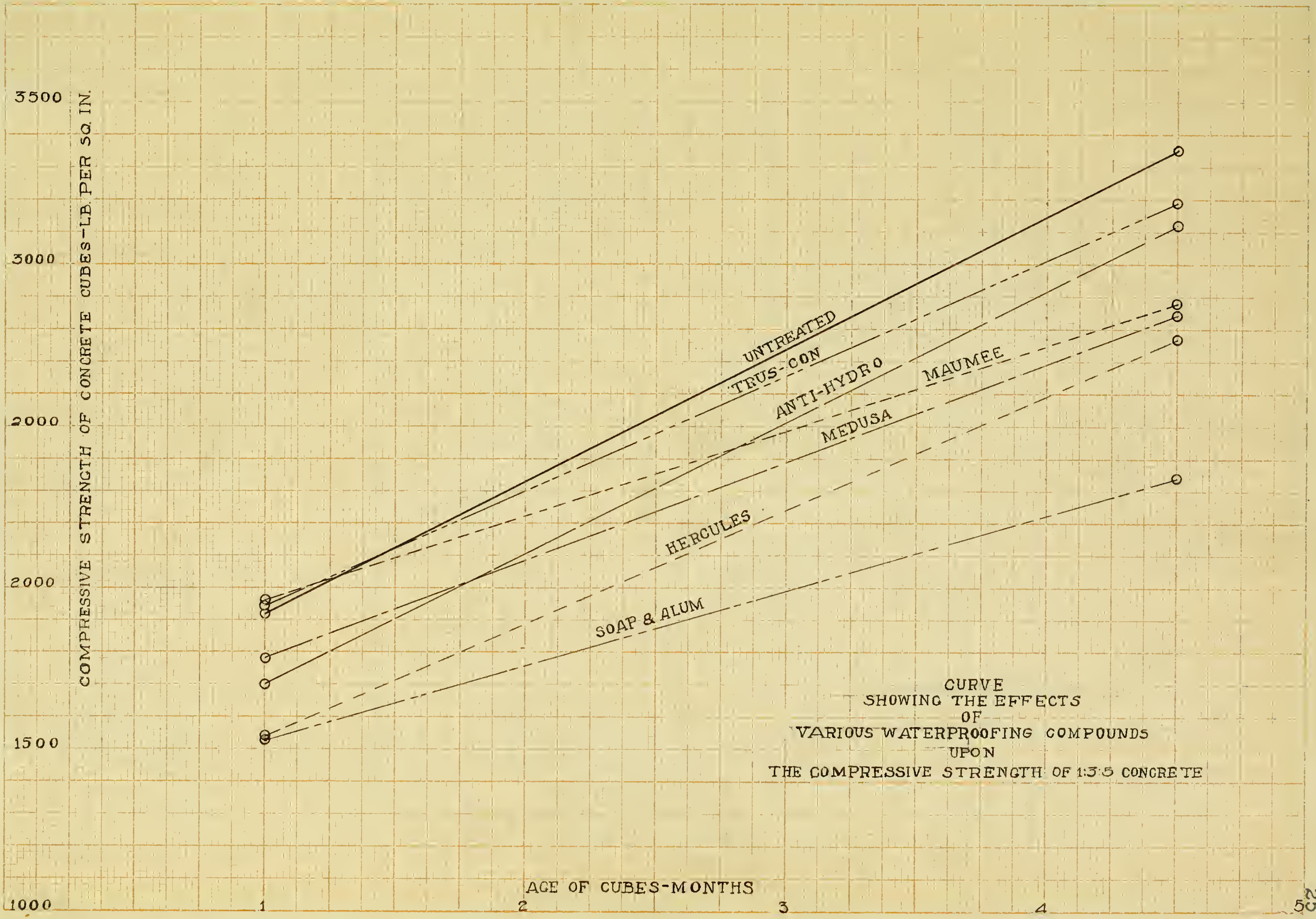
RELATIVE STRENGTH OF TREATED AND UNTREATED 1:3:5 CONCRETE.

Chicago AA Portland Cement,
Wabash Sand and Broken Limestone.

Waterproofing Compound Used.	Relative Strength	
	1 month	4½ months
None	100	100
Medusa 2% of the weight of the water	93	85
Maumee 2% of the weight of the water	100	86
Hercules 2% of the weight of the cement	81	83
Trus-Con 7.7% of the weight of the water	99	95
Anti-Hydro 10% of the weight of the water	89	93
Soap and Alum $Al_2(SO_4)_3$, 1% of the weight of the water Soap 3% of the weight of the water.	80	70


CURVE
SHOWING THE EFFECT
OF
VARIOUS WATERPROOFING COMPOUDS UPON
THE TENSILE STRENGTH OF NEAT CEMENT
UNTREATED
HERCULES
TRUS-CON
ANTI-HYDRO
MAUMEE
MEDUSA
SOAP&ALUM
TENSILE STRENGTH OF BRIQUETTES-LB. PER SQ.IN.
850
800
750
700
650
600
AGE OF BRIQUETTES-WEEKS
1
2
3
4
5
6
7
8
9
10
11
12
13





CURVE
SHOWING THE EFFECTS
OF
VARIOUS WATERPROOFING COMPOUNDS
UPON
THE COMPRESSIVE STRENGTH OF 1:3:5 CONCRETE

CONCLUSION.

The results of the tests described in the preceding pages seem to indicate that the general effect of the waterproofing materials tested is to reduce the strength of neat cement, 1:3 mortar, and concrete. However, some of the compounds increase the strength of cement mortar which has reached a considerable age, and where early strength would not be required the effect of the waterproofing would not need to be considered. Since there are such great variations in the strength of concrete and since the allowable stress is kept low on this account, it would seem that the reduction of the strength of concrete by the waterproofing compounds need not be considered in ordinary design. The claims made by the manufacturers of some of these waterproofing compounds that the strength of the concrete is greatly increased by the use of the compound, are not substantiated by the results of these experiments.